Geophysical Research Abstracts
Vol. 19, EGU2017-17493, 2017
EGU General Assembly 2017

On the paleo-magnetospheres of Earth and Mars

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The intrinsic magnetic field of a terrestrial planet is considered to be an important factor for the evolution of terrestrial atmospheres. This is in particular relevant for early stages of the solar system, in which the solar wind as well as the EUV flux from the young Sun were significantly stronger than at present-day. We therefore will present simulations of the paleo-magnetospheres of ancient Earth and Mars, which were performed for ∼4.1 billion years ago, i.e. the Earth's late Hadean eon and Mars' early Noachian. These simulations were performed with specifically adapted versions of the Paraboloid Magnetospheric Model (PMM) of the Skobeltsyn Institute of Nuclear Physics of the Moscow State University, which serves as ISO-standard for the Earth's magnetic field (see e.g. Alexeev et al., 2003).

One of the input parameters into our model is the ancient solar wind pressure. This is derived from a newly developed solar/stellar wind evolution model, which is strongly dependent on the initial rotation rate of the early Sun (Johnstone et al., 2015). Another input parameter is the ancient magnetic dipole field. In case of Earth this is derived from measurements of the paleomagnetic field strength by Tarduno et al., 2015. These data from zircons are varying between 0.12 and 1.0 of today's magnetic field strength. For Mars the ancient magnetic field is derived from the remanent magnetization in the Martian crust as measured by the Mars Global Surveyor MAG/ER experiment. These data together with dynamo theory are indicating an ancient Martian dipole field strength in the range of 0.1 to 1.0 of the present-day terrestrial dipole field.

For the Earth our simulations show that the paleo-magnetosphere during the late Hadean eon was significantly smaller than today, with a standoff-distance r_s ranging from ∼3.4 to 8 $\mathrm{R_e}$, depending on the input parameters. These results also have implications for the early terrestrial atmosphere. Due to the significantly higher EUV flux, the exobase of a nitrogen dominated atmosphere would most probably have been extended above the magnetopause, leading to enhanced atmospheric erosion, whereas a CO_2-dominated atmosphere would have prevented atmospheric loss in such a scenario. Our simulations also show that the Martian paleo-magnetosphere during the early Noachian must have been comparable in size to the terrestrial paleo-magnetosphere, hence a CO_2-rich atmosphere should have been protected by the magnetic field from rapid atmospheric erosion until the cessation of the Martian dipole field ∼4.0 billion years ago. Finally, our results favor the idea that the young Sun must have been a slow to moderate rotator. The solar wind and EUV flux from a fast rotating Sun would have been so intense, that most probably the ancient atmospheres of Mars and Earth would not have survived.

Acknowledgments. The authors acknowledge the support of the FWF NFN project "Pathways to Habitability: From Disks to Active Stars, Planets and Life", in particular its related sub-projects S11604-N16, S11606-N16 and S11607-N16. This presentation is supported by the Austrian Science Fund (FWF) and the US NSF (EAR1015269 to JAT).